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## SCIENTIFIC REPORT

BETWEEN 8000 AND 10,000 cm-1 (I - i.25 Micron Region) ABSORPTION BY CO2

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of the important bands and the half-widths of several lines have been measured. Tables of transmittance versus wavenumber are included for both regions as well as photographs of most of the spectra. Also presented are tables of the integrated absorptance  $\frac{1}{V} A(V) dv \text{ versus} V \text{ for both regions.}$ n at a pressure of 2.5 atmos-Spectra were obtained for region (1.0 µ) and 8000 obtained The absorption by CO<sub>2</sub> in the 9300 to 9650 cm<sup>-1</sup> region ( $1.0~\mu$ ) and 800 to 8325 cm<sup>-1</sup> region ( $1.2~\mu$ ) have been studied. Spectra were obtained for four samples of CO<sub>2</sub> in the 1.0  $\mu$  region at a pressure of 2.5 atmorpheres and path legnths up to 932 meters. Spectra were obtained for ten samples of CO<sub>2</sub> in the 1.2  $\mu$  region at pressures as high as 15 atmospheres for yath lengths up to 32.9 meters and pressures as high

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#### SECTION 1

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INTRODUCTION AND SUMMARY

and the centers of several of the bands with very good accuracy; but very little can be learned about the strengths or widths of the abcell which was capable of very long paths and obtained their spectra Most of the important absorption bands of CO, in the region between 8000 and 10,000 cm<sup>-1</sup> have been observed by Hérzberg and Herzberg. They measured the positions of many of the lines These workers contained their samples in a multiple-pass absorption sorption lines from their data, photographically.

transmission over an extremely wide variation of paths, including those in which the pressure, temperature and the mixing ratio of CO2 with The present investigation was undertaken to obtain spectra of samples From the results covering a wide range of pressures and path lengths. From the results included in this report, the strengths of nearly all of the lines of any importance and the widths of several of them can be determined. From this information, one can, at least in principle, calculate the other gases might vary.

should be able to determine the amount of  ${\rm CO}_2$  in the Martian atmosphere. The band near 9500 cm<sup>-1</sup> is of particular importance at the present time in the interpretation of spectra of the atmospheres of Mars and Venus. It occurs in a region free of absorption lines of other atmospheric very nearly independent gases; therefore, spectra of the planetary atmospheres can be obtained from the earth's surface. This band is so weak that its integrated absorptance in the Martian atmosphere should be very nearly independer of the pressure of the gas. Thus, by comparing the planetary spectra with laboratory spectra such as some of those presented below, of the pressure of the gas. The band near 9500 cm

Once the amount of  ${\rm CO}_2$  is known, the pressure can be determined by investigating other bands in which the absorption is a function of both the smount of  ${\rm CO}_2$  and the total pressure.

the various features of the bands. The strengths or absolute intensities, of the important bands have been determined, and the half-width of several of the lines have been measured. Section 4 includes a table of transmittance versus wavenumber for 14 different samples studied. Section 5 contains tables of the integrated absorption  $\{A(v)dv\}$  for the same samples; from this table the integrated absorptions over virtually any region of interest in the bands can be determined. Spectra of several samples are shown in Section 3 with a discussion of

### SECTION 2

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## EXPERIMENTAL METHODS AND NOTATION

## 2.1 APPARATUS AND PROCEDURE

The shorter cell has a base a base length of passes, giving a Samples of CO<sub>2</sub> were contained in two different absorption cells which have been described previously. The longer cell has a base length o as 32 passes. 0.9 meters in It can be evacuated or pressurized to as much as 15 atmospheres. diameter and can be evacuated to less then one micron of Hg or as many The longer cell has and was used at as many as 32 It is approximately approximately I meter and was used at pressurized to as much as 2.5 atmospheres. total path length of 933 meters. previously. approximately 30 meters length of

The CO<sub>2</sub> was drawn from the vapor in a dewar which contained both liquid and vapor at a pressure of about 300 psig and a temperature of ap<sub>1</sub>-roxinately -20°C. We found that semples obtained in this manner contained taken from commercial absorption in the region between approximately absorption does not appear in more recent spectra of samples witained impurities, particularly  $H_2O$ , than samples taken from commerciaess at room temperature. A spectrum published previously by us impurity since the 9530 and 9560 cm-1 which is apparently due to an cylinders at room temperature. in the manner described above. amount of shows a small

was studied with a grating having 300 lines/mm and blazed Overlapping orders were eliminated in this region by the use The spectra were obtained with an Ebert type spectrometer whose main The region from 9000 to 10,000 cmgrating naving 1200 lines/mm and blazed at 0.8 µ. Both gratings have a ruled area of 64 x 64 mm. first order and a Tiffen glass filter eliminated The region between 8000 wavelengths. mirror has a 75 cm focal length. overlapping orders of shorter a silico. window. in the was scanned with a 9000 cm and

considerably better signal-to-noise ratio (S/N) could probably be achieved in the region between 9000 and 10,000 cm<sup>-1</sup> with a photomultiplier detector. not necessary to cool the detector below dry ice temperature for operation in this wavelength region, but the dewar on the detector was designed to the extra sensitivity of the photomultiplier was not required in in the higher wavenumber region the slits were opened until a dostrable therefore, more convenient and was used since the signaliiquid Most of the spectra However, the extra sensitivity or the process, the bands in this order to obtain spectra from which the strengths of the bands in this region was receive can be determined. The S/N in the 8000 - 9000 cm<sup>-1</sup> region was region can be determined. The S/N in the 8000 - 9000 cm<sup>-1</sup> region was enough higher than in the higher wavenumber region that we could con-⋖, used as the detector. Cooling by io-noise ratio was approximately the same at both temperatures. in the lower wavenumber region were obtained with sufficiently spectral resolution that many or the lines could be resolved. for use at longer wavelengths. veniently work with a smaller spectral slitwidth. A PbS cell cooled with liquid nitrogen was hold liquid nitrogen nitrogen was,

positions 3-i and W venumber calibration was obtained for each spectrum from the of the absorption lines and band centers designated in Figures 3-2, most of which are from Herzberg and Herzberg.

The raw spectra were replotted and digitized by the use of apparatus A computer program was then used to colculate values of transmittance and integrated absorptance described in Appendix C of reference 2. which are shown in Sections 4 and 5.

## 2.2 DEFINITIONS, SYMBOLS AND NOTATIONS

the geometrical path length of the radiation as it passes through a sample, p is the pressure of the  $00_2$  which is measured in atmospheres unless otherwise specified, and u is the absorber thickness given by **5** 

$$a = W p L \frac{273}{296} (atm cm_{STP}).$$
 (2-1)

in this cause  ${
m CO}_2$  to deviate from a perfect gas at some of the pressures used a factor that accounts for the Van der Whals' forces which investigation. It is given adequately for our purposes by <del>1</del>8

$$W = 1.00 + 0.0047 p. (2-2)$$

Equation (2-1) is then equivalent to the thickness of a  ${\rm CO}_2$  sample at 1 atmosphere pressure and 273°K having the same number of molecules per standard temperature (2730K) and room temperature (2960K) at which all The quantity 273/296 accounts for the difference in density between of the measurements were made. The absorber thickness given by unit area as the sample being described.

of CO<sub>2</sub> is small compared to that of N<sub>2</sub>. Burch, Gryvnak and Williams<sup>4</sup> have found that throughout most of the spectrum an equivalent pressure Although this investigation deals only with samples of pure  ${\rm CO}_2$ , it is frequently desirable to relate the pressures to an equivalent pressure This is necessary when dealing  $P_{e}$  of a dilute mixture of  ${\rm CO}_2$  in  ${\rm N}_2$ . This is necessary when dewith paths through the earth's atmosphere in which the partial given by

$$P_{a} = 1.5 p + (P - p)$$
 (2-3)

Variations that the equivalent.

dilute mixture of CO<sub>2</sub> in N<sub>2</sub>. The factor 1.3 recent to lines by N<sub>2</sub>. It is valid whility of CO<sub>2</sub> lines by N<sub>2</sub>. It is valid whility of CO<sub>2</sub> to the broadening ability of CO<sub>2</sub> lines whose centers are in the shapes of the extreme wings of CO<sub>2</sub> absorption lines give rise to the difference in the relative broadening abilities. The line shapes of different broadening sases will be discussed in a report to be published It is noted within a few cm<sup>-1</sup>; but it is not valid in regions such as on the high wavenumber side of the  $v_3$  and  $3v_3$  bands where the absorption is due to the extreme wings of lines whose centers are several cm<sup>-1</sup> away. Variat that the equivalent pressure approaches the total pressure for a very can be used where P is the total pressure due to both gases, by us in the near future.

prcbably is proportional to the density of molecules, Equation (2-3) should probable modified to account for the non-linearity between pressure and density Since the simple classifical theory predicts that the half-width of a line The modification can be made in the following way: higher pressures.

$$P_{p} = 1.3 \text{ W p} + (P - p).$$
 (2-31)

with an instrument having infinite T'(v) is related to the absorption crefficient K(v) by T(v) is the observed transmittance and  $A(v) \equiv 1 - T(v)$  is the observed absorptance. T'(v) and A'(v) are the transmittance and absorptance, respectively, which would be observed with an instrument having infin resolving power.

$$T'(v) = \exp \left[-u K(v)\right] \quad \text{or } - \operatorname{Lm} T'(v) = u K(v).$$
 (2-4)

is the band strength, or band intensity, and is related to the absorption coefficient due to the band of interest by  $\alpha$  is the half-width of an absorption line and is expressed in cm<sup>-1</sup>.

$$S_{V} = \int K(v) dv. \tag{2-5}$$

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### SECTION 3

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## DISCUSSION OF ABSORPTION BANDS

## IDENTIFICATION AND FEATURES OF THE ABSORPTION BANTS 3.1

were calculated from energy levels tabulated by Stull, Wyatt and Plass. 7 In the notation for the transitions, the lower level is omitted when it is 0000. The strengths of the different portions of the bands are Table 3-1. The positions of the band centers measured by Herzberg and Herzberg  $^1$  and by Courtoy<sup>6</sup> are listed. Centers of the other bands All of the  ${\rm CO}_2$  banus which one mitth expect to produce appreciable absorption in the region from 8000 to 10,000 cm are listed in described in Section 3.2. Table 3-1.

to each other. These bands, along with their associated difference bands, occur in the region from 9300 to 9650 cm<sup>-1</sup>. The changes in each the same for the difference bands as for the of the quantum numbers are the same for the difference bands as for the combination pands, but the difference bands arise from transitions from the quantum number All of the bands arise from transfithree (3) in  $v_3$ , the quantum number,  $v_1 = 2v_2$ , the bands arising from The bands occur in two groups, one between 9300 and 5650 cm<sup>-1</sup> and the other between 8000 and 8325 cm<sup>-1</sup>. All of the bands arise from transiclose arising associated with  $v_3$ . Since, for  $CO_2$ ,  $v_1 = 2v_2$ , the bands arising transitions from the ground stace to  $20^{0.3}$ ,  $1.7^{0.3}$ , and  $04^{0.2}$  occur tions in which there is a change of three the 01 to state. Because of anharmonicity, a difference band usually occurs at a slightly lower wavenumber than its associated combination or fundamental band. However, the displacement of the difference band varies from one band depending on the Fermi resonance. to another,

POSITIONS AND STRENGTHS OF ABSORPTION BANDS

Band Center cm <sup>-1</sup>	ter	Transition	Portion	Strength atm cm cm STP cm 1
9631.38	нн	20 <b>°</b> 3	R-Branch F-Branch Entire Band	1.4 <sup>+</sup> 0.13 × 10 <sup>-5</sup> 1.25 <sup>+</sup> 0.14 × 10 <sup>-5</sup> 2.6 <sup>-</sup> 0.25 × 10 <sup>-5</sup>
9629.6	SWP	$21^{1}3 - 01^{1}0$	Entire Band <sup>c</sup>	2.0 × 10 <sup>-6</sup>
9517.00	Ħ	12 <sup>0</sup> 3	K-Branch P-Branch Entire Band	3,40 ± 0.2 × 10 <sup>-5</sup> 3.23 ± 0.5 × 10 <sup>-5</sup> 6.63 ± 0.7 × 10 <sup>-5</sup>
9478.2	SWP	1313+0110	Entire Band <sup>c</sup>	5.2 2. 20-6
9389.02	H	04 <b>°</b> 3	R-Branch P-Branch Entire Sand	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
9320.1	SWP	05:3-0110		sot measurable
8294.01	нн	1003	R-Branch P-Branch Entire Band	8.4 ± 0.5 × 10 <sup>-4</sup> 8.6 ± 0.6 × 10 <sup>-4</sup> 17.0 ± 1.0 × 10 <sup>-4</sup>
8276.83	НН	11 <sup>1</sup> 3+01 <sup>1</sup> 0	Entire Band <sup>c</sup>	1.5 × 19 <sup>-4</sup>
8243.2 8231.6 8220.0	SWP SWP SWP	$20^{\circ}_{2}^{\circ} - 10^{\circ}_{0}$ $12^{\circ}_{3} - 02^{\circ}_{0}$ $10^{\circ}_{3}$ ( $c^{12}_{0}^{16}^{16}$ )		Not observable Not observable
8192.62	Ē	02 <sup>0</sup> 3	R-Branch P-Branch Entire Rand	6.0 ± 0.5 × 10-4 5.8 ± 0.5 × 10-4 11.8 ± 0.9 × 10-4
8135.95	HK	(3 <sub>1</sub> 3+01 <sub>1</sub> 0	Encire Band	1.0 ± 0.2 × 10 <sup>-4</sup>
8128.8 8119.7 8103.7	SWP SWP SWP	$^{12}_{02^{\circ}_{3}+10^{\circ}_{0}}$ $^{(c^{12}_{0}^{16}_{0}^{18})}_{04^{\circ}_{3}+c_{2}^{\circ}_{0}}$		Not observable Not observable Not observable
8089.01	ပ	$10^{\circ}3$ $(c^{13}0_2^{16})$	Entire Band	2.5 <sup>+</sup> 1 x 10 <sup>5</sup>
a_	,     	,12,16		

 $^{a}$ Transitions for isotope  $^{\mathrm{C}^{12}\mathrm{O}_{2}^{16}}$  unless otherwise specified.

bathority for position of band center. HH and C refer to Herzberg and Herzberg and C respectively SWP denotes that band centers were calculated from energy levels tabulated by Stull, Wyatt and Plass.

Strengths of ilfference bands were calculated from combined strengths of difference band and associated combination band by use of Equation (3-3).

bands is apparent. The magnitude of the noise in the spectrum can be seen in the region above about 9650 cm<sup>-1</sup>, as well as in the regions just above the heads of the other bands. All the spectra used in the analysis The upper panel shows a photograph of an original spectrum of a different were obtained with wider slits in order to reduce the noise to less than region are shown in Figure 3-1 with the sample studied in this investigation; it was obtained with the spectral The curve in the lower panel is a replot of the original spectrum of the largest rather noisy, but the structure in the P-branch of the three stronger clitwidth sufficiently wide that the structure of the band was lost. This spectrum is positions of the band centers indicated in the lower panel. sample obtained with considerably narrower slits. the 9390 - 9650 cm<sup>-1</sup> 2 or 3% of the signal. Spectra of

The  $20^{\circ}3$  and  $21^{1}3+01^{1}0$  bands are not resolved and appear as a single band since their centers are separated by only about 1.8 cm<sup>-1</sup>. The  $13^{1}3+01^{1}0$  band overlaps the P-branch of the  $12^{\circ}3$  band, with evidence of the head of the former at about 9495 cm<sup>-1</sup>. The  $04^{\circ}3$  band is weaker than the other not included in the spectrum shown. Only a hint of absorption could be observed on the spectrum of our largest sample in the region where this two; its associated difference band (0513-0110 band) is very weak and band should occur.

and occur along with their associated difof Figure 3-2. f the 10°3 band with the head of the difference band near the center of the  $10^{\prime\prime}3$  band. The effect of the difference band on the absorption near  $8280~{\rm cm}^{-1}$  can be seen easily in the spectrum of Sample 8. The  $C3^{1}3-O1^{1}0$  band also The 10<sup>0</sup>3 and C2<sup>0</sup>3 bands are separated by approximately 100 cm<sup>-1</sup> and ow in the region between 8000 and 8325 cm<sup>-1</sup> along with their associated ference bands. Figures 3-2 and 3-3 show spectra of several different presence is more apparent since the band head occurs further from the The numbers enclosed in rectangles 3-2. The positions of the centers 8. The C3-J-v1 combination band (0203); of the difference band near the center of the  $10^{0}$ 3 center of the 1113-0110 band occurs in the P-branch of the the sample numbers listed in Table 3-2. The positions of the more important bands are indicated in the lower panel occurs in the P-branch of its associated samples obtained in this region. center of the stronger band.

in order to observe the lines of these bands between the much The difference bands due to transitions from the 020 and 100 states largest samples if they bands. Resolution considerably better than that employed in this investigation would be were not overlapped by the lines of stronger bands. could probably be seen in the spectra of our stronger ones. "SALES OF THE STREET, " STREET, ST.

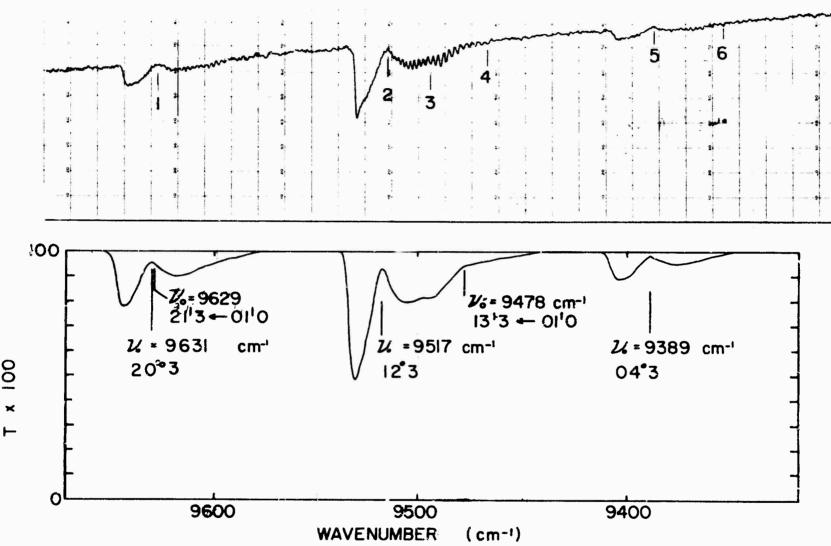


FIGURE 3-1 TRANSMISSION SPECTRA OF THE 9300 - 9650 cm<sup>-1</sup> REGION.

The upper curve is a photograph of an original spectrum obtained with a slitwidth of about 1.3 cm<sup>-1</sup> for a sample of pure  $\rm CO_2$  with p = 2.50 atm and u = 10.9 x 10<sup>4</sup> atm cm<sub>STP</sub>. The lower curve was replotted from a spectrum of Sample 4 (p = 2.50 atm, u = 21.7 x 10<sup>4</sup> atm cm<sub>STP</sub>) with a spectral slitwidth of 3.8 cm<sup>-1</sup>. The wavenumbers of the centers of the bands are indicated. Note that the wavenumber scales are not the sam in both panels. Wavenumbers of the points indicated in the upper pane. are: 1, 9631.4 cm<sup>-1</sup>; 2, 9517.00 cm<sup>-1</sup>; 3, 9495.33 cm<sup>-1</sup>; 4, 9467.50 cm<sup>-1</sup>; 5, 9389.02 cm<sup>-1</sup>; 6, 9356.23 cm<sup>-1</sup>. These points were used for wavenumber calibration.

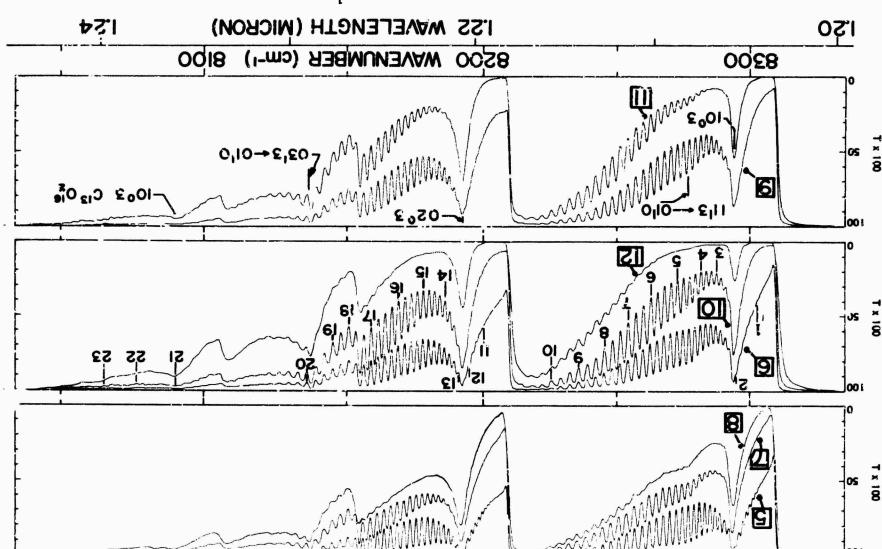


FIGURE 3-2 TRANSMISSION SPECTRA OF THE 8000 - 8350 cm-1 REGION.

The wavenumbers of the centers of the bands are indicated in the lower panel. Numbers enclosed in rectangles are sample numbers (See Table 3-2).

Wavenumbers of the points indicated in the middle panel are: 1, 8302.4 cm<sup>-1</sup>;

Secondary of the points indicated in the middle panel are: 1, 8302.4 cm<sup>-1</sup>;

Secondary of the points indicated in the middle panel are: 1, 8302.4 cm<sup>-1</sup>;

Secondary of the points indicated in the middle panel are: 1, 8202.0 cm<sup>-1</sup>;

Secondary of the points are indicated in the secondary of the secondary o

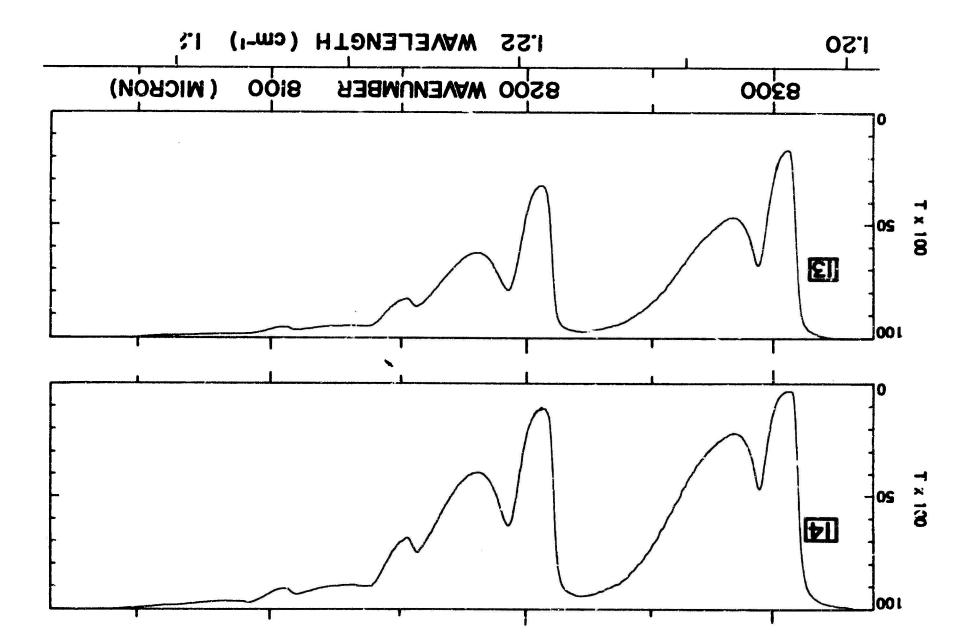


FIGURE 3-3 TRANSMISSION SPECTRA OF THE 8000 - 8350  $\rm cm^{-1}$  REGION.

The curves show spectra of samples 13 and 14 obtained at a pressure of 14.6 atm in order to smooth out the structure. These points were used

for wavenumber calibration.

TABLE 3-2

## SAMPLE PARAMETERS

Sample No.	P torr	p atm	u atm	u atm cm <sub>STP</sub>	L Path Meters	Spectral Slit./idth (cm <sup>-1</sup> )	Figure in which spectrum is shown
ر,	1900	2.50	5.51	× 10,	237	2.5	Not shown
2	1900	2.50	10.9	×	695	2.5	Not shown
3	1900	2.50	16.3	× 104	701	3.8	Not shown
4	1900	2.50		× 104	933	3.8	3-1
5	758	0.997	1.11	× 10 <sup>4</sup>	121	1.2	3-2
9	758	0.997		× 10,	237	1.5	3-2
7	758	0.997			695	1.9	3-2
∞	758	0.997		× 104	933	2.8	3-2
6	1920	2.53		× 104	121	1,5	3-2
10	1920	2.53		× 104	237	1,5	3-2
11	1920	2.53		× 104	695	1.9	3-2
12	1920	2.53	21.9	× 104	933	2,8	3-2
13	11,100	14.6	2.38	× 10,	16.5	1.1	3.3
14	11,100	14.6	4.73	× 104	32.9	1.1	3-3
-							

these isotopic bands could The 10°3 band of C<sup>13</sup>16 can be seen with its center at 8089.0 cm<sup>-1</sup>. It was identified as 02°3 by Herzberg and Herzberg<sup>1</sup> and later identified as 10°3 by Courtoy. Stull, Wyatt and Plass give 8089.0 cm<sup>-1</sup> for the band center of 10°3 and 7981.1 cm<sup>-1</sup> for 02°3. The latter band is very weak No attempt was made to change It is probably be sufficiently strong to be observed in the spectrum of our largest samples if they were not overlapped by lines of the stronger bands. the difference bands mentioned above, lines of these isotopic bands and will be discussed in a future report covering the region between 7100 and  $8000~\rm cm^{-1}$ . The  $10^{0.3}$  and  $02^{0.3}$  bands of  $\rm C^{1.2}0^{16}0^{18}$  should safe to assume that they occur in their natural abundances. the relative abundances of the isotopes in our samples. probably be seen with better resolution.

It is noted that all of the bands in this region have a rather sharp band head on the high wavenumber side of the R-branch, a feature which is typical of  ${\rm CO}_2$  bands having a change in the quantum number  ${\rm v}_3$  associated with  ${\rm v}_3$ . The heads of the bands included in this report occur near with  $v_3$ . The neaus of J = 44 in the R-branch.

## 3.2 BAND STRENGTHS

The strength, or intensity, of an absorption band is given by

$$= \int K(v) dv, \qquad (2-5)$$

where the integration is performed over all u for which there is appreci-K(v), the absorption coefficient, is defined by able absorption. Equation (2-4).

wavenumber,  $K(\vee)$  used in Equation (2-5) must include only the portion due to the band whose strength is being determined. The methods used to estimate the contributions of each band in overlapping regions are des-Of course, if more than one band contributes to the absorption at cribed below

This is less than the spectral slitwidth used in obtaining spectra of Samples 13 and 14 (Figure 3-3). Consequently, the observed transmittance  $T(\nu)$  is very nearly the true transmittance  $T'(\nu)$ . By combining Equations the pressure is increased, the lines are broadened until at 14.6 atm, the maximum pressure used, the half-widths are of the order of 1.3  $\rm cm^{-1}$ However, as (2-4) and (2-5), we see that we can determine the band strengths from The strengths of the bands included in this report are essentially independent of pressure over the range of pressures used. the spectra by use of the following equation.

$$v_{\rm v} = -\frac{1}{u} \int m T(v) dv.$$
 (3-1)

cm-1 region. Therefore, the strengths of these bands were determined from spectra of samples contained in the longer absorption cell whose maximum pressure is 2.5 atmospheres. At the pressure T'(v) may be quite different from T(v); but Equation (3-1) can still be used, provided  $A(v) \equiv 1 - T(v)$  is not too large. A more detailed discussion of the limitations on (3-1) when deal-9650 Equation (3-1) was used to determine the strengths of all the hands in the 8000 - 8325 cm<sup>-1</sup> region from Samples 13 and 14, except for the  $10^{03}$  band of  $10^{13}$ 0. It was not possible to use samples in the shorter absorption cell with sufficiently large absorber thickness to produce more than a few percent absorptance by this band or by the bands in the 9300 - 9650 ing with samples at relatively low pressures is given in Reference 8.

For  $\Sigma$ - $\Sigma$  bands (quantum number  $\hat{\mathcal{L}}=0$ ) of CO<sub>2</sub>, the strength S of a given line within a band is related to the band strength S<sub>v</sub> by

$$S_{m} = S_{v} \mid m \mid \exp \left[ -\frac{B'' m(m-1)}{k\theta} \right] q_{r}. \tag{3-2}$$

The Q-branch is missing the rotational constant of the lower state, k is Boltzmann's constant, 0 is the temperain  $\Sigma \leftarrow \Sigma$  bands, and contains only about one percent of the strength of  $\mathbb{R}+\mathbb{R}$  bands ( $\mathcal{L}=1$  as in  $21^{+}3+01^{1}0$ ). Equation (3-2) also gives the strengths of lines in the P- and R-branches of  $\mathbb{R}+\mathbb{R}$  bands. Gray and Selvidge have tabulated values of r rtition functions and relative line strengths for -<u>.</u> different types of  ${\rm CO}_2$  bands at several temperatures. -J for the P-branch. ture, and Qr is the rotational partition function. for the R-branch and

According to quantum theory, the relative strength of the difference band  $21^{1.3} \div 01^{1.0}$  to its associated summation band  $20^{6.3}$  is given by is given by

$$\frac{s_{V}}{s_{V}} \frac{(21^{1}3 + 01^{1}0)}{(20^{0}3)} = 2 \exp(-hc 667.4/k\theta)$$
 (3-3)

 $= 0.078 \text{ for } \theta = 296^{\circ}\text{K}.$ 

h is Planck's constant, c is the speed of light and the factor 2 arises from the double degeneracy of the  $01^10$  state. 667.4 cm<sup>-1</sup> is the difference levels 0110 and 0000. the energy

associated summation or fundamental band if the proper degeneracy factor is used and 667.4 is replaced by the difference between the energy level  $00^{\circ0}$ 0 and the lower level for the difference band. (3-3) also relates the strength of any difference band to Equation

in Table 3-1. From Equations (3-1) and (2-1), we see that the units of band strength are atm<sup>-1</sup> cm<sup>-1</sup>, with the STP referring to the absorber thickness and not to the temperature at 'hich the measurement The strengths of all the bands of significance in the region are given

their strengths were calculated from their combined strengths by the use The R- and P-branches could be measured separately, by summing the strengths of the lines in each branch as given by (3-2). of Equation (3-3). The R- and P-branches could be measured separately, and their relative strengths are in good agreement with what we obtain Since the 20°3 and 2113+0110 bands are not separated in our spectra, The summation gives 52% for the R-branch and 48% for the P-branch.

The R-branch of the  $12^{0}$ 3 band is isolated from other bands and could be measured separately. But the P-branch is overlapped by the  $13^{1}$ 3-01-0 overlapped by the  $13^13 \div 01^10$  (3-3) to determine their making it necessary to use Equation strengths.

Therefore, The  $04^{\circ}3$  band is displaced from its associated difference band  $(05^{1}3+01^{1}0)$  and could be measured directly. There was only a Lint of absorption in our original spectra in the region where  $05^{1}3+01^{1}0$  should appear. Therefo its strength could not be measured; it could, of course, be calculated from the strength of the 043 band.

uncertainty are presented for the strengths of the difference bands since they would depend on the uncertainties of the associated combination bands and on the error in the theoretical relationship given by Equation (3-2). In some cases the uncertainty of an entire band is slightly less than the sum of the two branches since it is not pussible to divide the spectrum exactly to determine the contributions of each of

are relatively free The R-branches of the  $10^{\circ}3$  and  $02^{\circ}3$  bands of  $C^{1}2_{02}^{16}$  are relatively frof overlapping lines and were measured separately. Strengths of the  $11^{1}3$ +01 $^{1}0$  band and the P-branch of the  $10^{\circ}3$  band were determined from in the same manner as the bands discussed above. Equation (3-3)

 $03^13-01^10$  band, lines P2 to P34 are isolated. By summing the strengths of lines P2 to P34 as given by Equation (3-2), we found that these lines comprise 90.7% of the strength of the entire P-branch. Therefore, the strength of the P-branch was determined from fK(v)dv/.907 over the region a portion of the P-branch of the 0203 band is overlapped by the Allowance The correction was calculated by assuming shape and a half-width of 1.3 cm<sup>-1</sup>. (Thi was made for the contribution of the wings of these lines which would value of half-width is based on results shown in Section 3.3.) It not necessary to calculate the correction very accurately since it amounted to only a couple percent of the strength of the P-branch. band center to a point midway between P34 and P36. the lines have a Lorentz line shape and a half-width of 1. occur outside the interval.

strength of the  $03^13+01^10$  hand was then determined from  $\int K(\nu) d\nu$  over ference band with only a rather small correction based on a theoretical relationship. We see that the relative strengths are 1.0  $\times$   $10^{-4}/11.8$   $\times$ the interval covered by the band and subtracting the portion due to the P-branch of the 02°03 band. It was also necessary to account for the overlapping  $10^{03}$  band of  $\rm C^{13}0_{2}^{16}$ . By this method we were able to obtain values for the strengths of a combination band and its associated dif-0.085, which agrees, within experimental error, with 0.078 given by (3-3).Equation

the strengths of the bands of the two isotopes would be in the same ratio. This is seen to be true within experimental error. The ratio of strengths is  $2.5 \times 10^{-5}/17.0 \times 10^{-4} = 0.015$ , with approximately  $4.07 \times 10^{-10}$ If we assume that the sample contains 98.9% The percent of uncertainty for the strength of the  $10^{03}$  band of  $c^{13}_{02}$ samples in which the relative abundances of the various isotopes were is large because of the sizeable corrections which had to be made for the overlapping bands. The strength given for this band is based on the ratio of abundances = 0.011. not intentionally altered.  $c^{12}$  and 1.1%  $c^{13}$ , we would

## HALF-WIDTHS OF ABSORPTION LINES

ing the thinkey party that in the

ca-1 The shape of a collision-broadened  ${\rm CO}_2$  absorption line within a few of its center, can usually be represented by the Lorentz line shape of its center, equation, 5, 11.

$$k(v) = \frac{3}{\pi} \frac{\alpha}{(v - v_0)^2 + \alpha^2}.$$
 (3-4)

 $k(\nu)$  is the absorption coefficient of the single line;  $S_m$  is its strength,  $\alpha$  is proportional is the half-width. pressure while S and v are constant. and  $\alpha$ is the line center,

absorptance  $\int A(v)dv$ Ladenherg and Reiche lave shown that the integrated of a single line having the Lorentz shape 's given by

$$\int A(v) dv = 2\pi\alpha \stackrel{?}{\nearrow} (x), \qquad (3-5)$$

=  $Su/2\pi\alpha$ , and where x

$$\mathcal{F}(\mathbf{x}) = \mathbf{x} e^{-\mathbf{x}} \left[ J_0 (\lambda \mathbf{x}) - \lambda J_1(\lambda \mathbf{x}) \right] . \tag{3-6}$$

 $J_0(\omega,x)$  and  $J_1(\omega,x)$  are the Bessel functions of order 0 and 1, respectively

approximations can be readily used for single lines under certain conditions: Although Equation (3-6) is a rather involved expression, two well-known

$$\int A(v) dv = S_m u,$$
 for small x

(3-2)

(weak lines)

(strong lines). for large x

2 (S<sub>m</sub> u  $\alpha$ )<sup>1/2</sup>

 $\int A(v)dv$ 

and

(3-8)

for small A(v). have been tabulated by Kaplan and are equivalent (3-1)It is noted that Equations (3-7) and Values of  $\mathcal{F}$  (x) for intermediate (x) Eggers. 13

intermediate x; and even if the conditions for Equation (3-8) are not fulfilled,  $\alpha$  can still be determined by use of the exact expression given by Equation (3-5), provided x is sufficiently large that there  $\int A(\nu) d\nu$  is seen to be independent of  $\alpha$  for small x and p oportional to  $\alpha^{1/2}$  for large x. The dependence is less than anuars root for conditions if Sm is known. The dependence is less than square root for It is apparent from Equation (3-8) that  $\alpha$  can be determined from measurement of f(x) dv under the proper conditions if  $S_m$  is known is a sizeable dependence on  $\alpha$ .

significance; therefore, it was possible to measure  $\int A(\nu) d\nu$  for them. Values of  $S_m$  were obtained from the band strength given in Table 3-1 by the use of Equation (3-2); and values of  $\int A(\nu) d\nu$  were taken from Table 5-2 for each line. The absorber thickness u for Samples 6, 7 and 8 is great enough that x is sufficiently large for a near square-Lines P2 to P32 of the  $02^{o}3$  band are isolated from other lines of any root dependence of  $\int A(v) dv$  on  $\alpha$ . We assumed  $\alpha^0$  ( $\alpha$  at a pressure of 1 atm) to be 0.09 cm and used Equation (3-5) along with the tabulated values of  $\mathcal{F}(x)$  to calculate  $\int A(\nu) d\nu$  for these samples. The calculated values of  $\int A(\nu) d\nu$  were then  $\int A(\nu) d\nu$  for these samples. The calculated values of  $\int A(\nu) d\nu$  were then compared with the observed values; and, by a reiterative process, more accurate values of  $\alpha^0$  were obtained. In making the calculations, we accounted for slight overlapping of the lines which causes the integrated absorptance of  $\gamma$  region containing several lines to be less than the sum of the individual contributions we would expect without overlapping. The maximum correction to the calculated  $\int A(v) dv$  for overlapping was only about 5 percent. Results of a recent theoretical article by Plass  $\frac{1}{4}$  were used to calculate the overlapping correction factor.

pletely resolved in the spectra because of the slitwidth of the spectrumeter.  $\int A(\nu) d\nu \ \ \, \text{was \ calculated between points midway, to the nearest 0.1 cm^1,}$  between line centers. Because of the "rounding-off" of the position of Fig. 3-4; the various geometrical figures correspond to different samples from which the measurement was made. Much of the variation between values and not comintegral which should be attributed to one line might be attributed to The results of the  $lpha^{ extsf{O}}$  measurements are shown by the plotted points in the midpoint and hecause of slight calibration errors, part of the for adjacent lines is due to the lines being close together

solid line represents a mean value of o for lines P6 to 220 in the band which was determined by us a reconstruction from an empirical equation relating  $\alpha^{\rm O}$  to J which is given by Winters, Silverman and Benedict. <sup>11</sup> The equation is based on data in the 15 µ region by Madden. The dotted curve was obtained The solid line representation of  $00^{\circ}3$  band which was determined by us.

points is probably less than 0.01 cm<sup>-1</sup>. But beyond J = 22, the curve based on Winters, Silverman and Benedict drops off quickly while there is only a hint of drop-off in our data. The uncertainty for an average of our We see that there is reasonably good agreement among the sets of data for J between about 10 and 22.

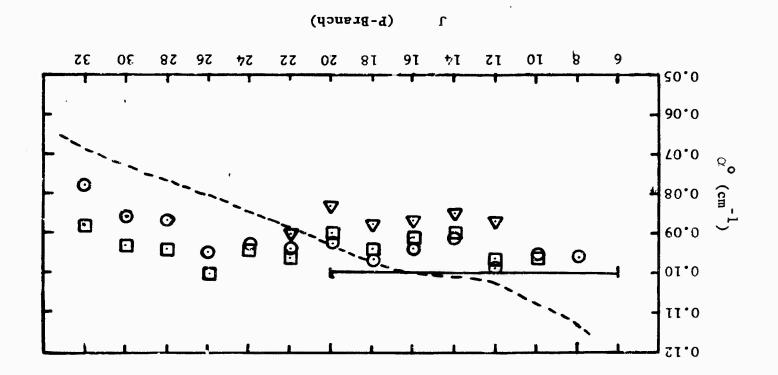


Fig. 3-4. HALF-WIDTHS OF SELF-BROADENED CO LINES

The various geometrical figures correspond to measurements based on different samples: A, 6; O, 7, and E, 9. Solid curve represents mean value for 00°3 band. Broken curve represents empirical equation by Winters, Silverman and Benedict<sup>11</sup> based on 01<sup>10</sup> band.

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#### SECTION 4

## TABLES OF TRANSMITTANCE

, respectively.
4-1 and at intervals small that the or ginal spectra could be approximated very closely by Tables 4-1 and 4-2 consist of values of transmittance, in percent, in the regions 9340 to 9650 cm $^{-1}$  and 8030 to 8340 cm $^{-1}$ , respectively. in Table 4-2. In both cases the interval is sufficiently the tabulated values and joining the points with straight The first and second columns give the wavenumber in vacuum Values are recorded at intervals of 1 cm<sup>-1</sup> in Table of 0.2 cm<sup>-1</sup> in Table 4-2 plotting the tabulated values and joining lines. The tirst and the wavelength in microns.

shown at the top of the corresponding column. Each .ample is designated by the same number as in Table 3-2 and in the spectra shown in The sample pressure p and absorber thickness u for each sample are Section 3.

smaller samples where the absorptance is very small. T(v) can be considered as 1  $(A(v) \ge 0)$ , for even the largest samples, from 9415 to 9430 cm<sup>-1</sup> and from 9530 to 9570 cm<sup>-1</sup>. Several of the spectra from which the tables were obtained, particularly those between 9340 and  $9660~cm^{-1}$ , represent the average of two or three original spectra Values are not tabulated over some portions of the spectra of the The wavenumber scale was calibrated by using the known positions of the lines indicated in Figures 3-1 and 3-2. which were scanned for the same sample.

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   | 17771  | 11111  | 44.44<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00<br>64.00 | 31111   
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  | 99,8 59,4 100.0<br>99,8 59,4 100.0<br>100.0 99,9 150.0<br>100.0 100.0   | 900.0 99.3 100.0<br>99.8 99.2 100.0<br>90.8 99.2 100.0<br>90.8 84.1 100.0  | \$4,2 94,1 105,0<br>94,1 34,1 109,0<br>94,0 94,0 100,0<br>94,0 94,0 100,0<br>94,0 94,0 100,0   | 0.001 8.40 1.00.0<br>0.001 84.9 100.0<br>0.001 84.9 100.0<br>0.001 84.0 100.0  | ##.#<br>##.#<br>##.#<br>##.#<br>##.#<br>##.#<br>##.#<br>##.   
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189,8    | 160.4 149.9 160.6 186.8<br>160.9 140.0 160.9 166.9<br>160.3 160.0 160.6<br>160.0 160.0 160.0   | 199,¢ 199,0 199,0 198,0<br>195,6 186,0 199,0<br>195,5 186,0 199,0<br>195,9 185,0 199,0<br>195,9 185,6 195,0  | 100.0 100.0 100.0 100.0<br>100.0 100.0 100.0<br>100.0 100.0 100.0<br>100.0 100.0 100.0<br>100.0 100.0 100.0   | 100.0 100.0 100.0 100.0<br>100.0 100.0 100.0 100.0<br>100.0 100.0 100.0 100.0<br>100.0 100.0 100.0 100.0  
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Table 4-2 (continued)

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Table 4-2 (continued)

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		0.000	100.001	999.2	00000		*****	6 6 6 6 6 6	100.001	20000 20000 20000 20000
		00000	100.0 100.0 100.0 100.0		100.0 170.0 100.0 100.0	00000	9 4 9 9 6	999.1	100.001	999.0
1000.00		0.000	100.0 100.0 100.0 100.0	8 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	0.001	00000	00000	9699	100.0	23.52
100.001		00000	100.0 100.0 100.0 100.0	00000			~ # E	0 0 0 0 0 0 0 0 0 0 4 4 4 4 8 8	130.0	****
20000		00000	00000				# # # # # # # # # # # # # # # # # # #	****** ***** ***** ****		*****
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100.1 100.1 100.1 100.0 100.0 100.1	25255	00000		160.0	100.0	000000	100.0 100.0 100.0	99.9 100.0 100.0	0.001	*****************
00000	2000	00000	100.5 100.5 100.5 100.0	100.0	0.001	100.0	100.0 100.0 100.0	100.0	100.00	100.00
99999	20000	00000	00000		100.0	100.0	109.0 109.0 109.0	100.00	100.001	100.0
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100.0 100.0 100.0 100.0 100.0 100.0 100.0	22222	90000	100.0		100.0	0.0001	10000	100.0	100.0	000000
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00000	22222	00000	00000	00000	100.6	100.0	100.0			100.0
100.00		00000	100.0	1.001 0.001 0.001	100 100 100 100 100 100 100	100.0 100.0 100.0	100000	100.0	100.0	100.00
1001	***	0.00	0.00	100.	100.0	100.0	0.001	ن	100.0	100.0

#### SECTION 5

## TABLES OF INTEGRATED ABSORPTALCE

Values of the integrated absorptance are presented in Tables 5-1 and 5-2 for the  $9430-9660~\rm cm^{-1}$  and  $8030-8340~\rm cm^{-1}$  intervals, respectively. The integrals were calculated from the transmittance tables in Section 4 by assuming that the spectrum could be constructed by plotting the transmittance values and joining them with straight lines.

column, was chosen at a point where there was essentially no absorption. The integrated at orptance between any two wavenumbers listed can be found by subtracting the values tabulated at those two points. Values are tabulated at intervals of 5 cm<sup>-1</sup> in Table 5-1 which covers samples whose spectra have but little structure. Table 5-2 includes samples whose spectra have but little structure. Table 5-2 includes samples whose spectra have considerable structure. Throughout most of the region, the integral is tabulated at points midway between the absorption lines. In regions where the spectra are smooth, tabulations are made at intervals of 5 or 10 cm<sup>-1</sup>. The lower limit of integration v', which is shown at the top of each

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2, 10 2, 10 2, 17 2, 10	2°20 1°63 1°00 1°00 1°00	2.500 1.095 1.095 1.095	P(erm)  b(erm)  b(erm)	501 x 00 x	2.500 2.500 1.635	1.095 2.500 2.500	2.50 2.51 5.51 2.51 2.51	(erm) u (erm) b(erm)	2.50 2.17 2.17 2.17	001 × 001 × 005.2	215 n(upu ca) h(upu)
0256-14	0126-14	0256-14	( c=c)	0E96#+A	0646- 'V	0640.v	t - === 00:96=,^	(1-m)	04Ce.'v	1. <sup>800</sup> 0 <del>9</del> 66*,^	( <sup>1-m</sup> )
•3	-5	-0	0.2112	•ŏ	- 5	•3	•5	0.01.0	.3	•3	0.04.2
500.0	100-5	-0	0.27.94	130.0	*6.7-5	.00	·ŏ	0.2449		10.5	3.24.6
700.0 980.0	653.0 100.0	-0	0.0622	100.0	200.0	200.20	003.3	0.3442	0.5.8	100"0	0.025
921.0	¥13.3	010*6	06	0.025 0.06#	380.0 140.0	160°0 010°0	910°0 003°3	0°2576 0°5776	643.0	550.0 110.0	0.0419
716.0	691.0	1 90 0	0"5"56	591"0	181.2	470°C	1.5210	3*\$596	4.1.0	8+1 °0	0.23.9
025.0	\$16.0	<11.0	0.0336	136.0	906.0	211.0	160.3	0*4746	576.0	152.0	0.0150
70H 0	302.7	712.0	9.53.6	184.0	059.0	241-0	661.0	0-5976	025.0	465.2	0.2119
129*1	367.0	565°0 246°0	9.2139	9<6*0 669*0	414.0	192*0	505.0	0.0149	746.0	845.0	0.2559
		****		044.00	+1) + " )	Z#£ *J	665.0	0.27#8	Z#5-0	283.0	J*\$926
\$* C44	124.1	441.0	0.0530	1.238	1.022	456.0	F1E.3	0.0649	531*1	121.0	0.0255
5"260	151-1	656.0	0.25.9	1.664	996.1	467.0	555.0	0.2846	19291	678-9	3.2040
2.952	920.5	701°1	0.0530	166.5	1.936	1.085	064.0	0.0546	159-1	921-1	0.0375
655-5	2.210	791°i	0.25.59	3.224	3.0.6	195"1	100-1	0"5676	291.5	255*1	0.2340
124.8	899.5	797° [	0.0.79	271*9	8++.5	050"2	162.1	0.0026	-515°Z	926*1	0.0119
AG6.A	174.6	766'1	0.2439	991"5	965.4	*39 ° 2	585.1	0.2329	AS2.5	218.1	0 \$175
101.8	4.214	2,508	0.0239	011.9	130.8	691.6	598*1	0.0122			0*\$1>5
5,06.8	556.2	TEE.S	6*5596	556.9	B16.2	996"6	160.5	0.2120			
5,865	556.4	TEE.S	0.0432	272.7	683.8	667.4	2.199	0.3526			
				+29*8	cto.T	75577	503.5	0*\$256			
				720 01	200 W	196"5	207 L	0.06.99			
				10.01	70°582	90519	909°E	0.2520			
				12.51	10.328	56.9	056 °C	0.3486			
				12,531	85E.01	526.9	3,950	0*5955			
				12.531	#SE.01	526.9	056.€	0.0556			

## Table 5-2 $\left[ \int_{\nu} A(\nu) d\nu \right]$

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	- <b>!!</b>	000		0.000		00000	0.909		2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.	41144	4.4.7.4.4 5.6.1.9.4 5.6.1.9.4 5.6.1.9.4	0.320 10.160 11.632 12.372	11.090	19.402 19.462 10.272 16.273	20.036	23.00 23.100 23.200 23.300		27.22	22.23 23.23 23.23 24.23 25.23 26.23	46.023 37.084 38.283			27.7.	
,	a 18 18	ACQ#.		79.72	0,7,8 2,7,8 1,1,4,0 1,4,	2.50 2.50 2.50 2.50 5.50 5.50	7.72 7.72 11.74 11.74	24.01 24.01 11.01 11.01 11.01	14.912	77.74	2.17 2.17 3.00 11.00 10.		127.18	4	94.22 94.623 71.42.		26.03 81.37 87.173		97.467 166.652 105.278 106.532 106.718	110.05	121.431	126.31. 127.72 129.603 130.754 130.754	196.004	
	= 5, 4,						2.700 2.700 3.607 6.141																	
	= 27 2	9		0.000	0.13 0.23 0.73 0.73 0.73 0.73	00000	0.1. 1.00.1 1.00.1 1.00.1 1.00.1	22.44	44.44 44.44	7.00		10.11 10.11 10.11	22.112 23.012 24.413 24.413 25.413	22.55	22.21 52.021 53.001 57.01	######################################		:::::	11.1.4	11.03.11		60.029 60.029 70.139 71.943	76.42 75.42 75.37 80.27 80.34	90.00
	, ge 3	a digital	*	9.05	0.0000000000000000000000000000000000000	00000	30000			24.4			10.50	10.20 10.20	20.01	25.334 25.561 25.561 25.618	25. 42. 26. 35. 26. 36. 26. 31. 26. 31.	20.00	91,240 10,240 11,240 16,191 15,469	37.31. 34.71. 60.71.	7777		11.22.1	
							1. *C. * * * * * * * * * * * * * * * * *																	
	,	1	į, į	0.00	22.25	20000	0.411 0.411 1.519 1.919	**************************************	3.510 3.510 3.710 5.210	7.276	10.77	2100	11.25		22422	777.78	**************************************	11.08 12.72 12.72 12.72 11.73 11.73	10000	,	10.10	40.05 40.05 40.05 11.000 11.000	34.245 38.245 38.366 38.763	7.05 7.05 1.05 1.05 1.05 1.05
		1			00000	00.1100	00000	0.402 0.947 1.237 1.734	1.700	7000 000 000 000 000 000 000 000 000 00		26.4.4	. • • • • • • • • • • • • • • • • • • •	10.537	10.01 11.01 11.01 11.01 11.01	17.000 19.791 17.771	12.4 12.4 12.4 12.4 12.4 14.4 14.4 14.4	******	22.15.2	26.01 26.22 26.22 27.72	70.00	3C.367 31.902 32.902 32.903	***************************************	
	,	9			0.00 0.00 0.00 0.00 0.00 0.00	0.020	0.004 0.124 0.213	00000	0.74	**************************************		1.00.00 1.00.00 1.00.00 1.00.00	9.19 9.19 9.00 9.00 111	4444	6.947 6.947 12.179 10.991		11.4411	11.845 12.841 12.841 13.645	13.787		11.00	20.02 20.02 20.02 20.03 20.03	22.61	25.100
			0.00.0	000	8064.C 8066.4 8066.7 9071.0	0079.4 0071.4 0071.4	90000000000000000000000000000000000000	20.00 20.00 20.00 20.70 20.00	1100.3	8144.3 815.2 8155.0 8157.7	2.02.2 2.02.2 2.02.2 2.02.2	0.1.1. 0.1.0. 0.1.1. 0.0. 0	200729		4300.4 6304.0 6304.0 6304.0	0.0220 0.2200 0.220 0.200 0.00	0237.i 0265.4 0265.6 1266.6	0792.6 0795.4 0796.4 0263.1	0706.3 073.3 0773.3	8778.2 8786.3 8787.4 8787.4		274.9 274.5 274.5 200.0 1.1	0365.9 0307.5 0312.5 0312.5	9323.0

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### SECTION 6

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